Relating DPR Measurements of Reflectivity to Path-Integrated Attenuation

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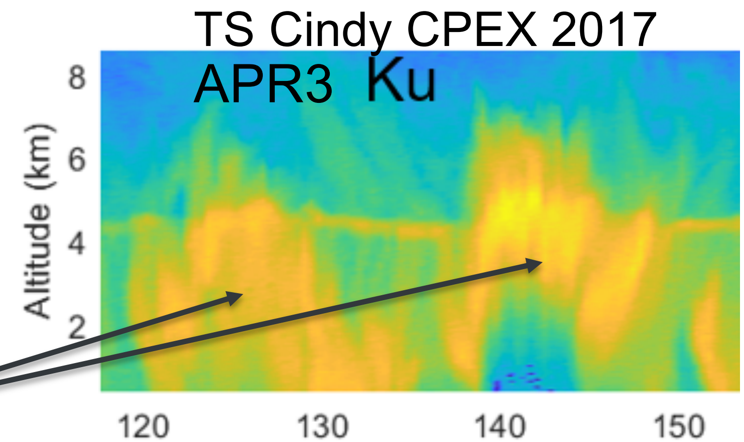
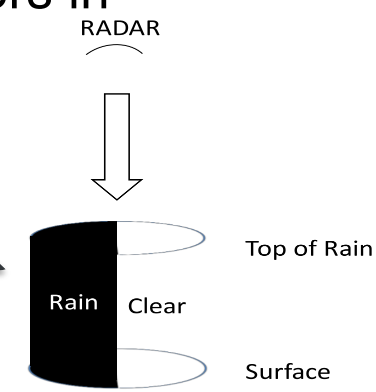
Motivation: Nonuniform Beamfilling (NUBF)

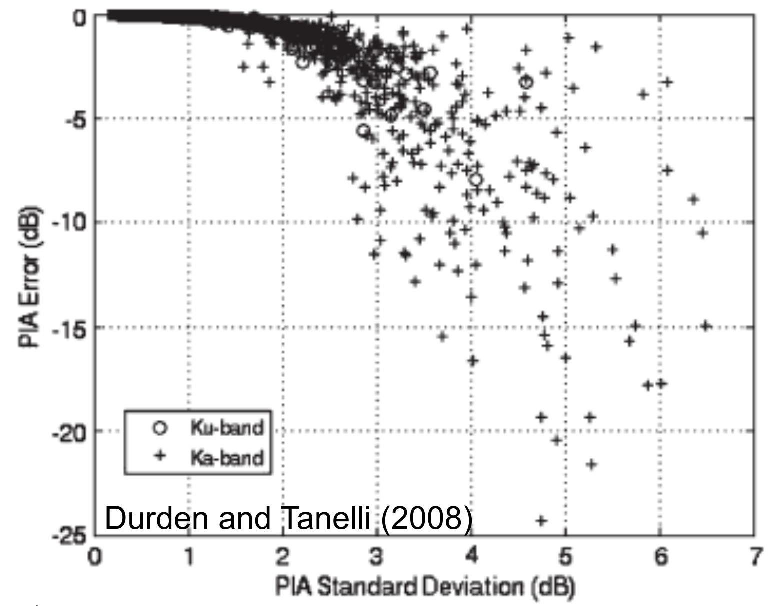
- Radar (e.g., APR3) and finescale rain gauge (or disdrometer) observations show
  - Variability at scales less than the DPR footprint size (5 km)
  - Present in some degree in all rain
  - Significant in convective rainfall
  - Also seen in OLYMPEX (see Durden NUBF poster)
- Previous studies have shown that NUBF can result in errors in measured Z and especially PIA using SRT
  - Classic example due to Nakamura (1991): half-filled footprint
  - Large PIA in rain but SRT PIA of only 3 dB
  - Z profile strongly attenuated





NUBF and PIA

- Ideal linear world, radar would provide average rainfall over the radar footprint (resolution volume)
- However, we measure average radar quantities and convert to rainfall
  - nonlinearity causes this to differ from averaged rainfall
- Our study from 2008 using airborne radar data compared PIA due to the average rain in the footprint with PIA derived from average surface backscatter
  - The SRT compares raining and non-raining backscatter, so is based on average transmissivity

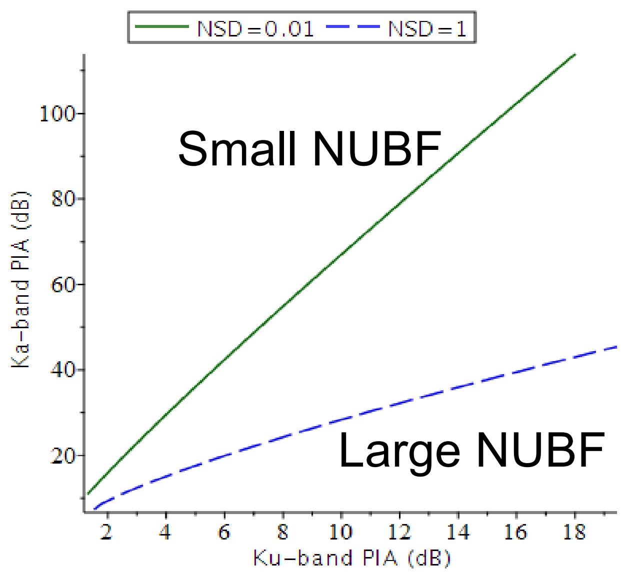


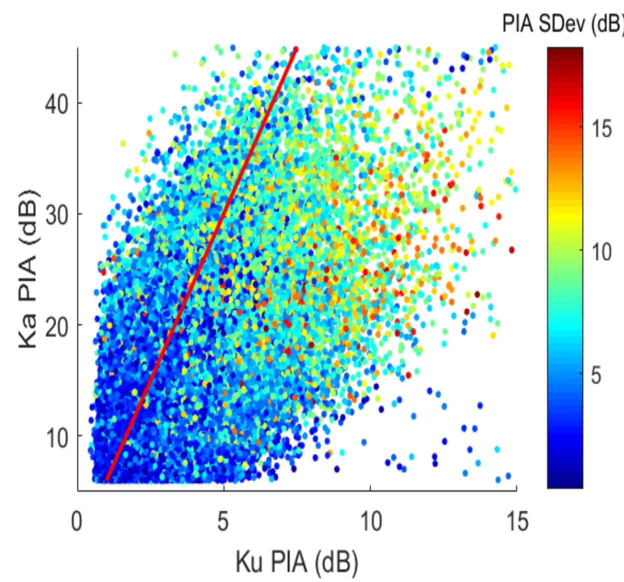
The horizontal axis is PIA std dev within low-res footprint

Most cases have small SRT error

NUBF and Dual-Frequency Radar

- Theory also predicts underestimation of PIA via SRT, with larger underestimation at higher frequencies (lower left)
- Hence, ratio of observed Ka-to-Ku PIA should decrease when NUBF is present (Tanelli, presentation this morning) – seen in GPM, below





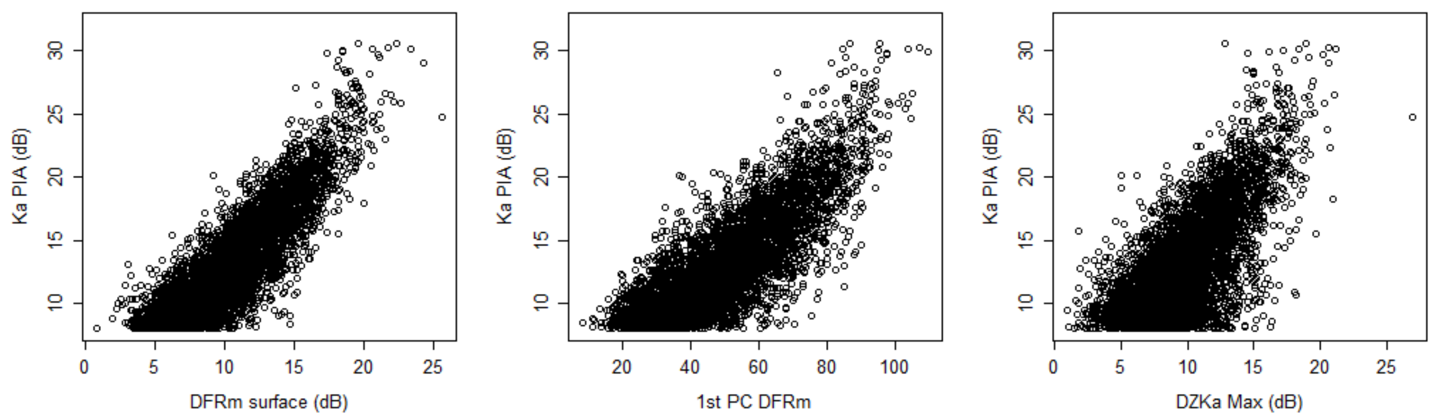
PIA SD based on 9 values at each point (including surrounding MS and HS)

Alternatives to SRT with less NUBF Sensitivity?

- At low rain rates Hitschfeld-Bordan approach can be used, without SRT PIA; however, NUBF especially of concern at high rain rates
- Examination of radar profiles shows that the profile shape can be strongly affected by attenuation, especially at Ka-band
  - Can PIA be estimated directly from the measured reflectivity profiles?
  - If so, is the accuracy sufficient for use in GPM?
- Investigated these questions using 3-yr set of GPM DPR data
  - Concentrated on ocean cases (> 200000 profiles)
  - Extracted a set of profile statistics from Ku- and Ka-band and DFR profiles: near surface Z and Z ratio, max Z, difference in Z between top and bottom of profiles (in rain), principle components
  - Looked for correlations between profile stats and PIA

Training Set Construction and Results

- We are looking for a PIA estimator less affected by NUBF but are using PIAs from the SRT in the study; how to avoid NUBF?
  - Selected a “training” set of (smoothed) profiles
  - Filtered large set of DPR profiles by PIA variability and dual-frequency PIA ratio, resulting in ~5300 profiles

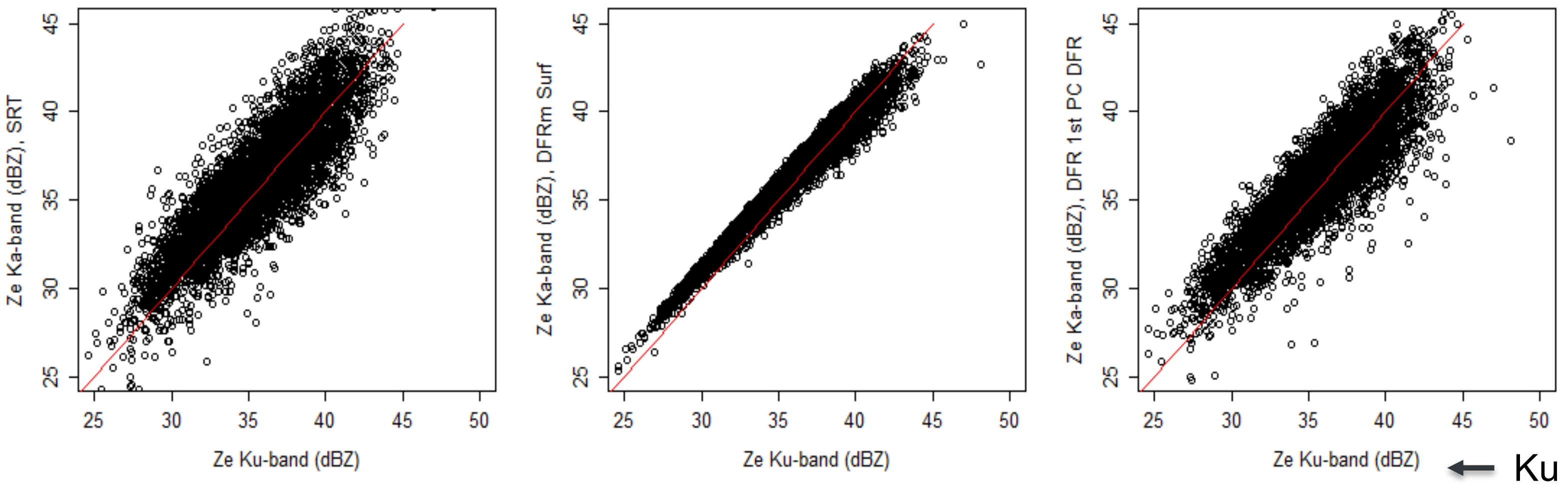


Durden IEEE TGRS (2018)

Scatter plots of Ka-band PIA versus quantities with correlation coefficients ≥ 0.7, for the small-NUBF training set. From left to right, *DFRm-surf*, 1st PC *DFRm*, and *DZKa*.

Linear Fits to PIA and Profile Stats

- Given correlation, looked for fits to data that could predict PIA from reflectivity profile statistics
  - 1^{st} order and 2^{nd} order fits between PIA and one profile stat
  - 1^{st} order fits between PIA and multiple profile stats
  - Slight improvement in RMS error with multiple or single 2^{nd} order; however, single 1^{st} order easiest to use and show (best RMS error ~ 2 dB)
  - Test fits by correcting near surface Z and compare with Ku-band Ze

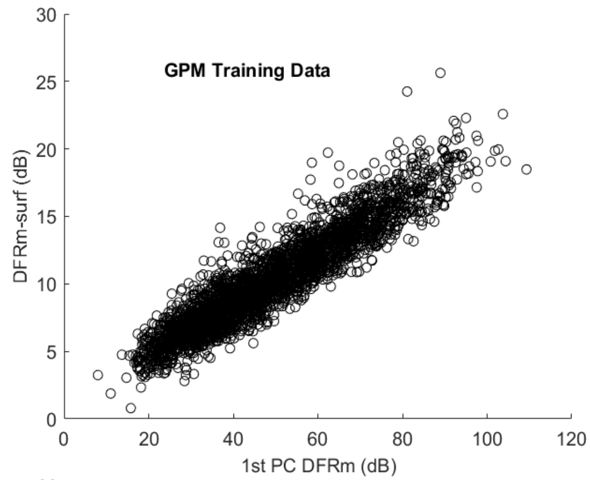


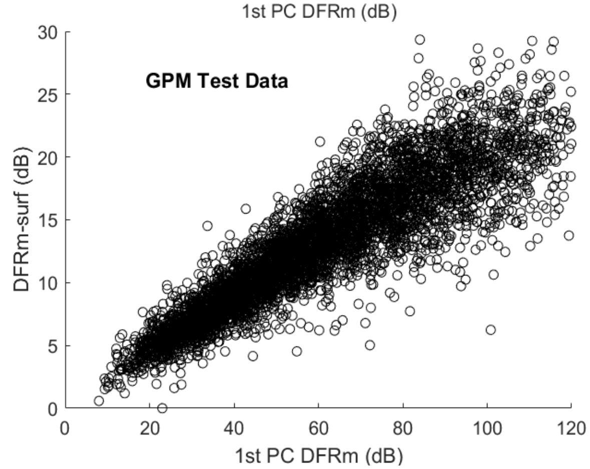
Some scatter due to delta Ze

← Ku Corrected with SRT

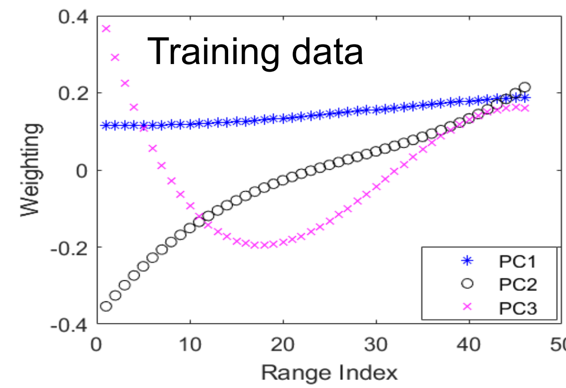
Tests on Independent Data

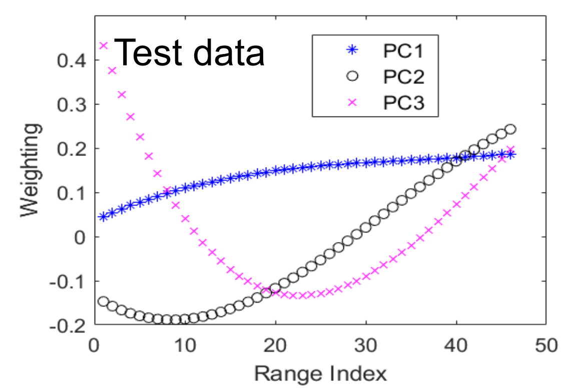
- Can relationships developed with 5000 profiles and small NUBF be extended to full DPR set of profiles with many cases of large NUBF?
- In spite of differences in NUBF, training and test data have similar principal components and similar relations between profile statistics





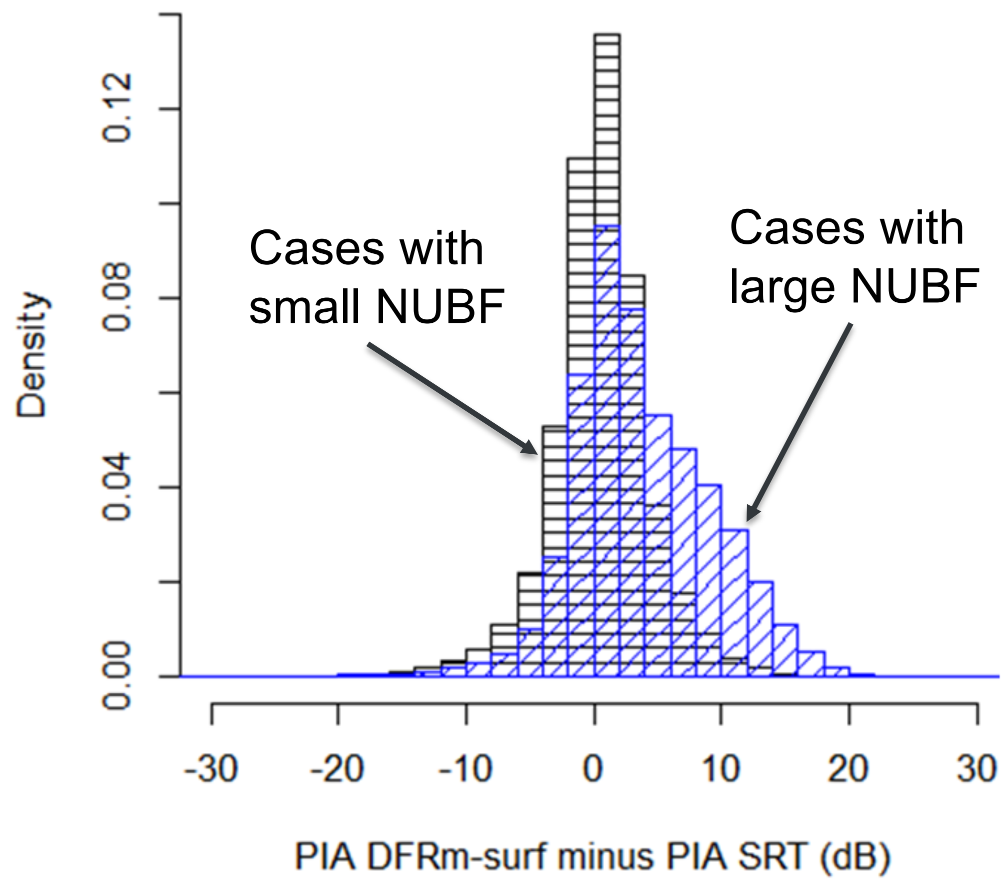
Principal components of measured DFR





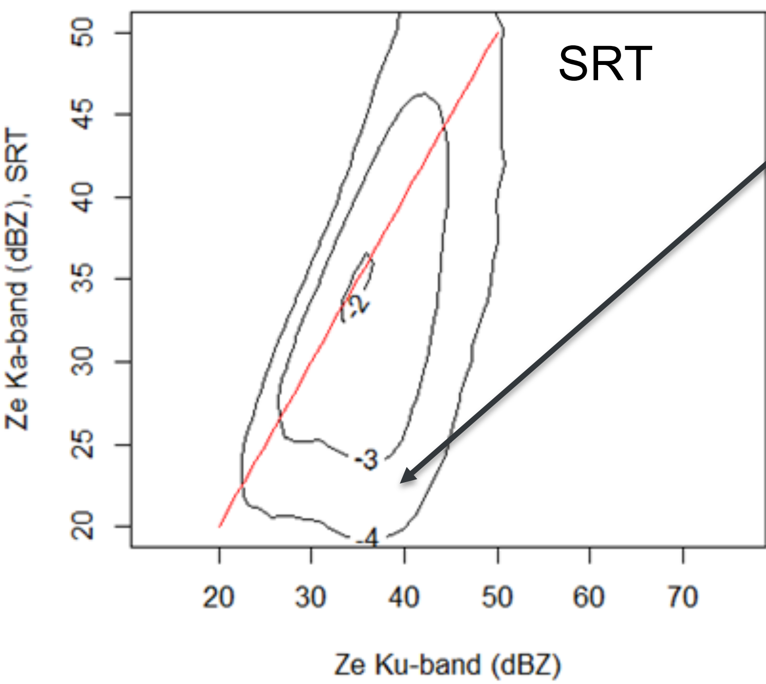
Test on Independent Data - Results

- Overlapped histograms of profile PIA minus SRT PIA
- Compare PIA for small and large NUBF (PIA ratio>4.5)
- Blue 45-degree hatching are cases with large NUBF
- Black with horizontal hatching have small NUBF
- When NUBF is present the SRT PIA is smaller than the PIA from the DFR profile

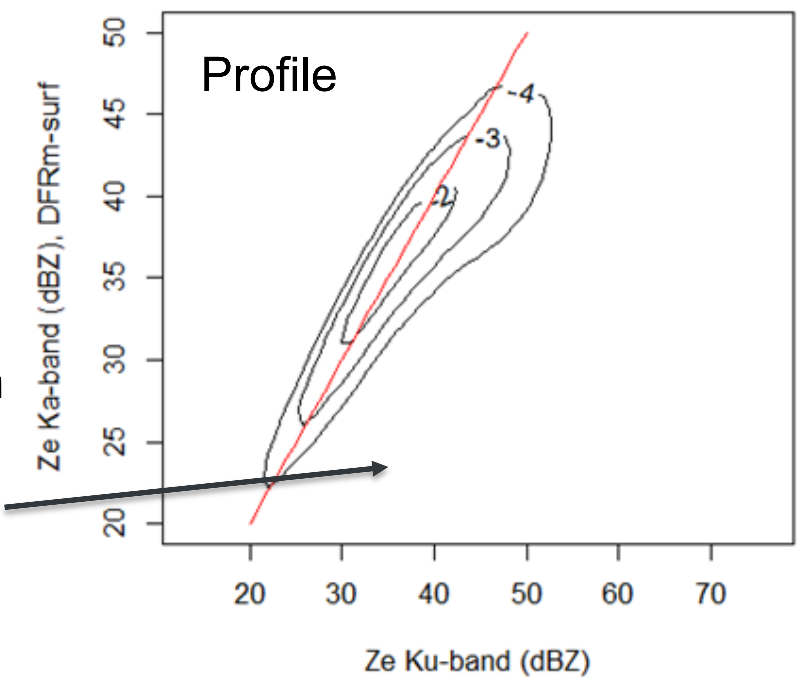


Comparison of Estimation of Near-Surface Ze

- As with training data, compare estimated Ze at Ka-band with Ze at Ku-band (Corrected with SRT product)
- Expect NUBF errors at Ku-band to be relatively small



Points with Ka-band Ze too low, not present in profile approach



Discussion and Summary

- Reviewed previous work on NUBF errors and showed evidence of expected errors in DPR data for situations with severe NUBF
- Hypothesized that profile is less affected by NUBF than SRT
- Results on training data showed that PIA and profile stats are correlated
- Results on test data indicated that PIA bias due to NUBF is reduced by using profile-based PIA
- Best profile statistic was near surface DFR; similar result found using airborne radar data by Meneghini et al. around 1990
  - Correlation for other parameters as well; can reduce RMS PIA errors using multiple regression with DFR, PCs, etc.
- RMS errors using profile are large but could be better than SRT in some cases of very severe NUBF (but w/ Ka-band); SRT best for most cases
- Performed similar analysis for land cases but all errors larger, probably due to large variability of surface sigma0 over land

Backup Slides

Test Data Set Histograms